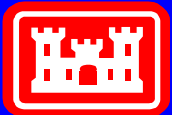# Silent Camp Hybrid System and Load Profile Sensitivity

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US Army Corps of Engineers

Engineer Research and Development Center

Presentation Outline

- **Intro to ERDC**
- **Problem Statement**
- **Silent Camp Concept**
- **Analysis**
- **Results**
- **Future Research**
- **Acknowledgements**

Soldiers, Families, and Civilians
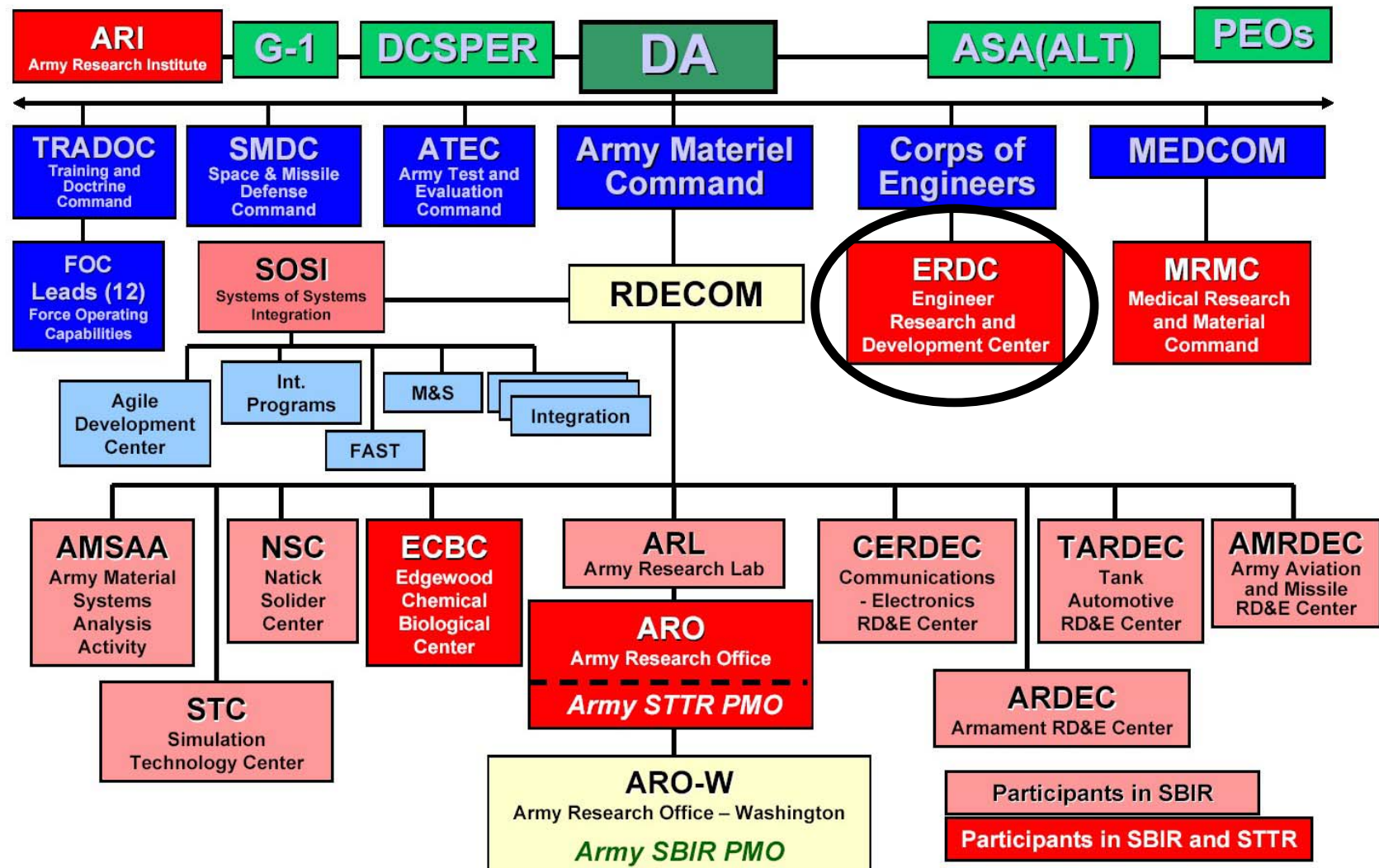
Home to the Force

Power Projection

Work & Training

… are our Customers!

ARMY R&D Organizations

ARI — Army Research Institute
G-1
DCSPER
DA
ASA(ALT)
PEOs

TRADOC — Training and Doctrine Command
SMDC — Space & Missile Defense Command
ATEC — Army Test and Evaluation Command
Army Materiel Command
Corps of Engineers
MEDCOM

FOC — Leads (12) — Force Operating Capabilities
SOSI — Systems of Systems Integration
RDECOM
ERDC — Engineer Research and Development Center
MRMC — Medical Research and Material Command

Agile Development Center
Int. Programs
M&S
Integration
FAST

AMSAA — Army Material Systems Analysis Activity
NSC — Natick Solider Center
ECBC — Edgewood Chemical Biological Center
ARL — Army Research Lab
CERDEC — Communications - Electronics RD&E Center
TARDEC — Tank Automotive RD&E Center
AMRDEC — Army Aviation and Missile RD&E Center

STC — Simulation Technology Center
ARO — Army Research Office
Army STTR PMO
ARDEC — Armament RD&E Center

ARO-W — Army Research Office – Washington
Army SBIR PMO

Participants in SBIR
Participants in SBIR and STTR

FY93-FY94 Phosphoric Acid Fuel Cell (PAFC) Project Sites

90 Fuel Cells
56 Sites
5 Manufacturers

- PC25A SITE
- PC25B SITE
- PC25C SITE

30 Fuel Cells
30 Sites
1 Manufacturer

FY01-FY04 Residential Proton Exchange Membrane Fuel Cell (PEMFC) Project Sites

Problem Statement
Forward Deployments

- **Base Camps and Other Forward Deployments Rely on Diesel (JP8) Fueled Generator Sets (GenSets) which are Inefficient, Noisy, Emit Pollutants, and are High Maintenance**

- **GenSet Sizes not Optimized for Loads – Results in Partial Loading of GenSets → Decreased Efficiency and Increased Maintenance (Wetstacking)**

- **GenSets Run Continuously 24 Hours / Day, 7 Days / Week**

- **Cost of Delivered Fuel to Forward Operating Positions Varies from ~ $40 per Gallon to $400 per Gallon**

- **Fuel Supply Lines Difficult to Defend Against Improvised Explosive Devices (IEDs) and Other Attacks → Bigger Issue than Fuel Cost**

Forward Deployments

- Base Camps
- Life Support Areas
- Advanced Operations Base
- Forward Operations Base
- Tactical Operations Center
- Etc.
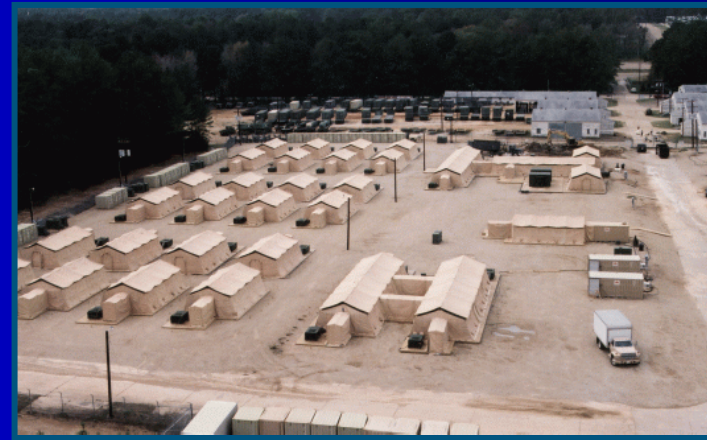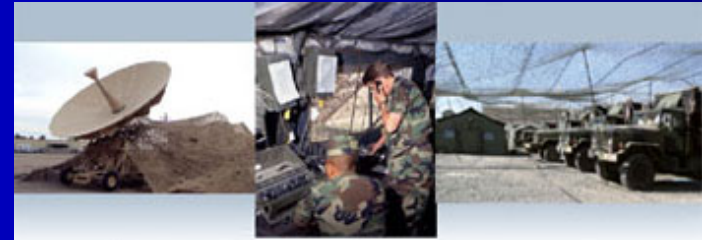
Military GenSets & Efficiency

Current DoD GenSet (2 kW – 60 kW) Inventory

Unit Rating (kW)	No. of Individual Units	Total Capacity (kW)
2	10,979	21,958
3	39,789	119,367
5	17,603	88,015
10	13,745	137,450
15	5,411	81,165
30	6,669	200,070
60	6,495	389,700
Total	*100,691*	*1,037,725*
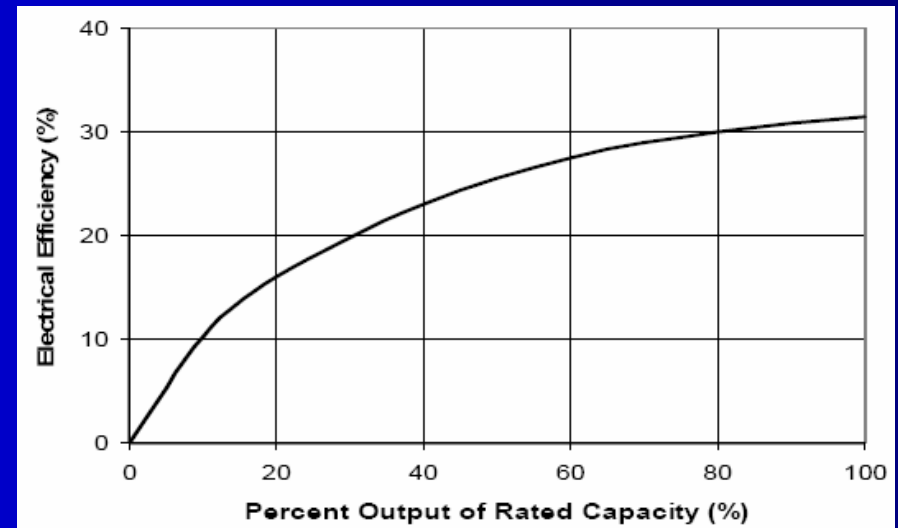
Partial Loading = Very Low Efficiency
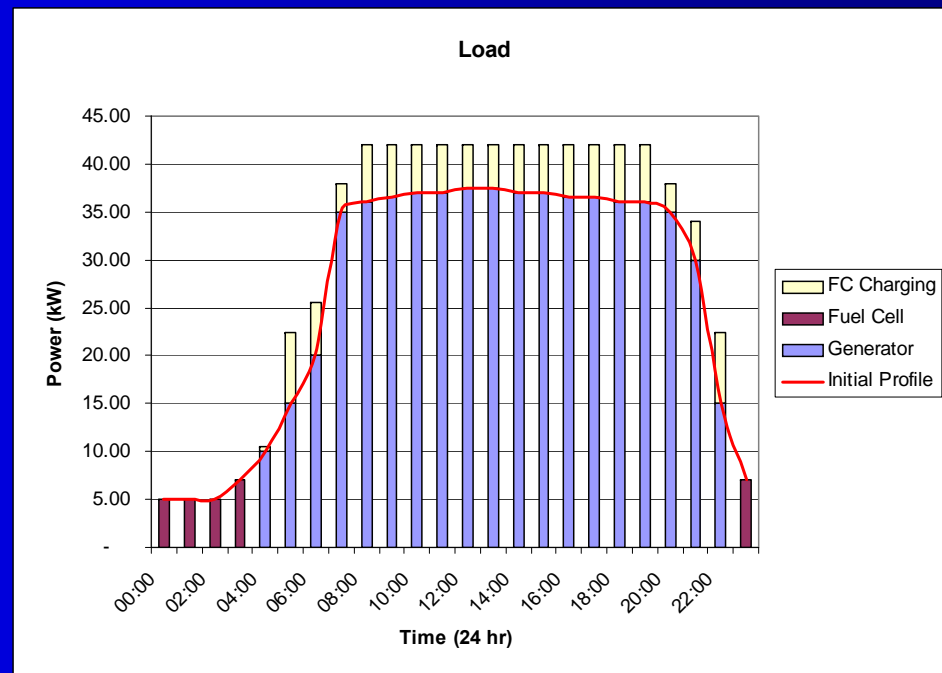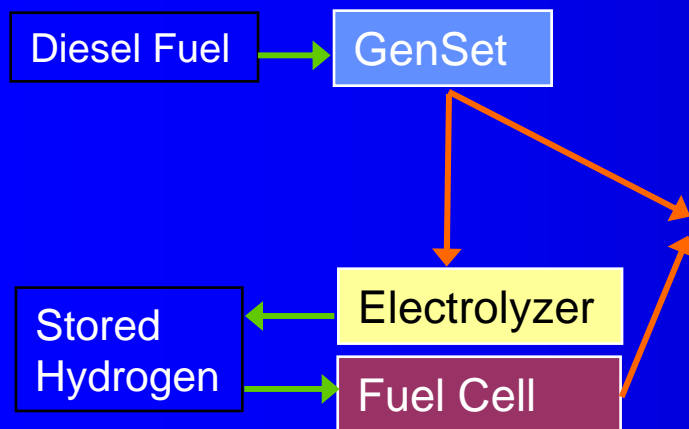

3 kW System

30 kW System

60 kW System

Silent Camp Concept

- **Increase GenSet Output to Electrolyze Water**
- **Store H2 Produced from Electrolyzer**
- **Use Stored H2 and Fuel Cell to Power Loads at Night**
- **Shut GenSet Off During Fuel Cell Operation**
- **Can Maximize Silent Camp Operation or Fuel Savings**


24 Hour Load Profile

MATLAB Model Parameters

- **Fuel Cell Size (kW)**

- **GenSet Size (kW)**

- **Electrolyzer Size (kW)**

- **Efficiency Curves for Fuel Cell, GenSet and Electrolyzer**

- **Constant Efficiencies For Storage And Inverter**

- **Load Profile Input (Demand by Interval-Assumed to Repeat)**

Actual Tactical Operations Center (TOC) Load Profile
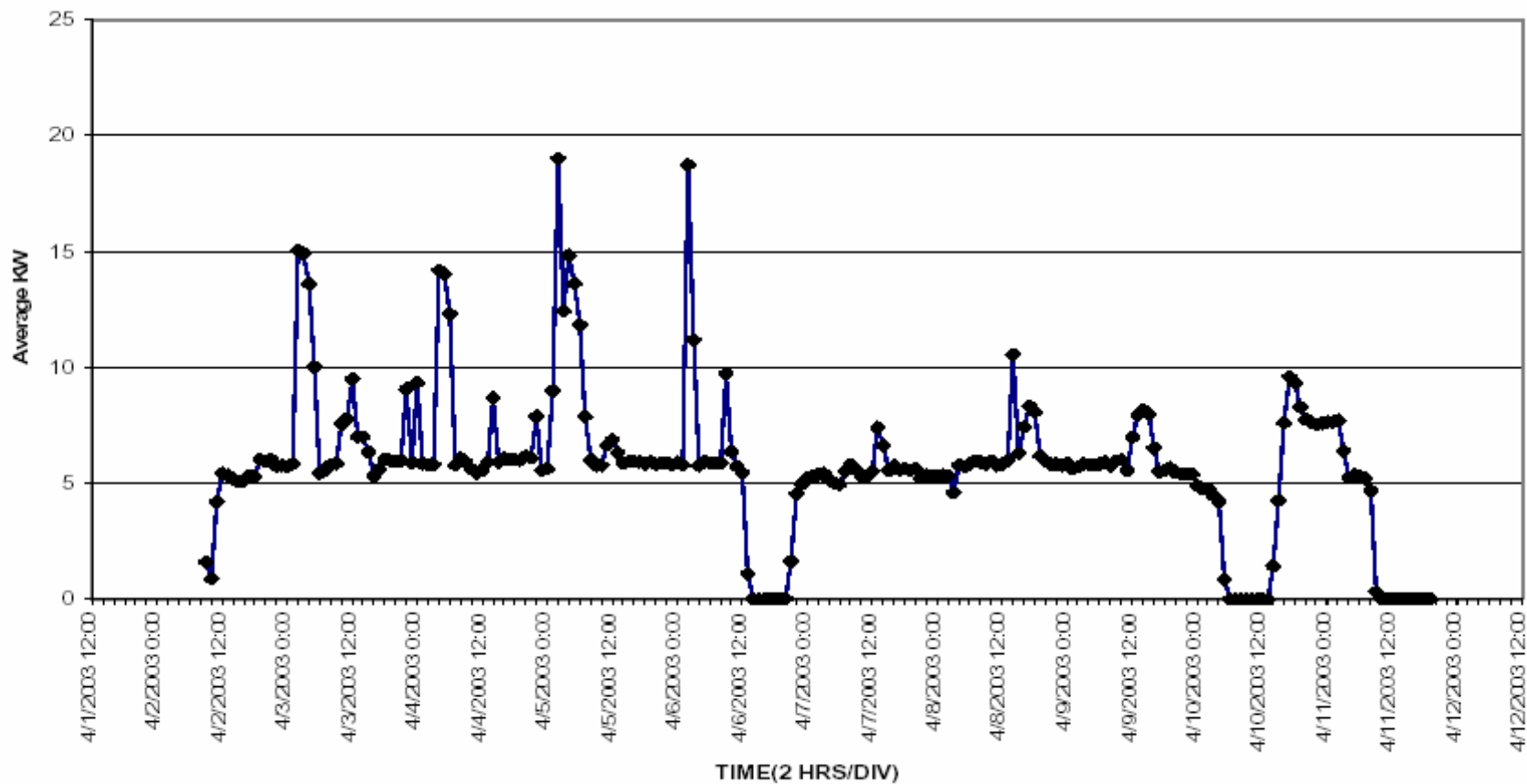
Silent Camp Results – Subset of TOC Data

Legend: Generator | Fuel Cell | FC Charging | Base Profile
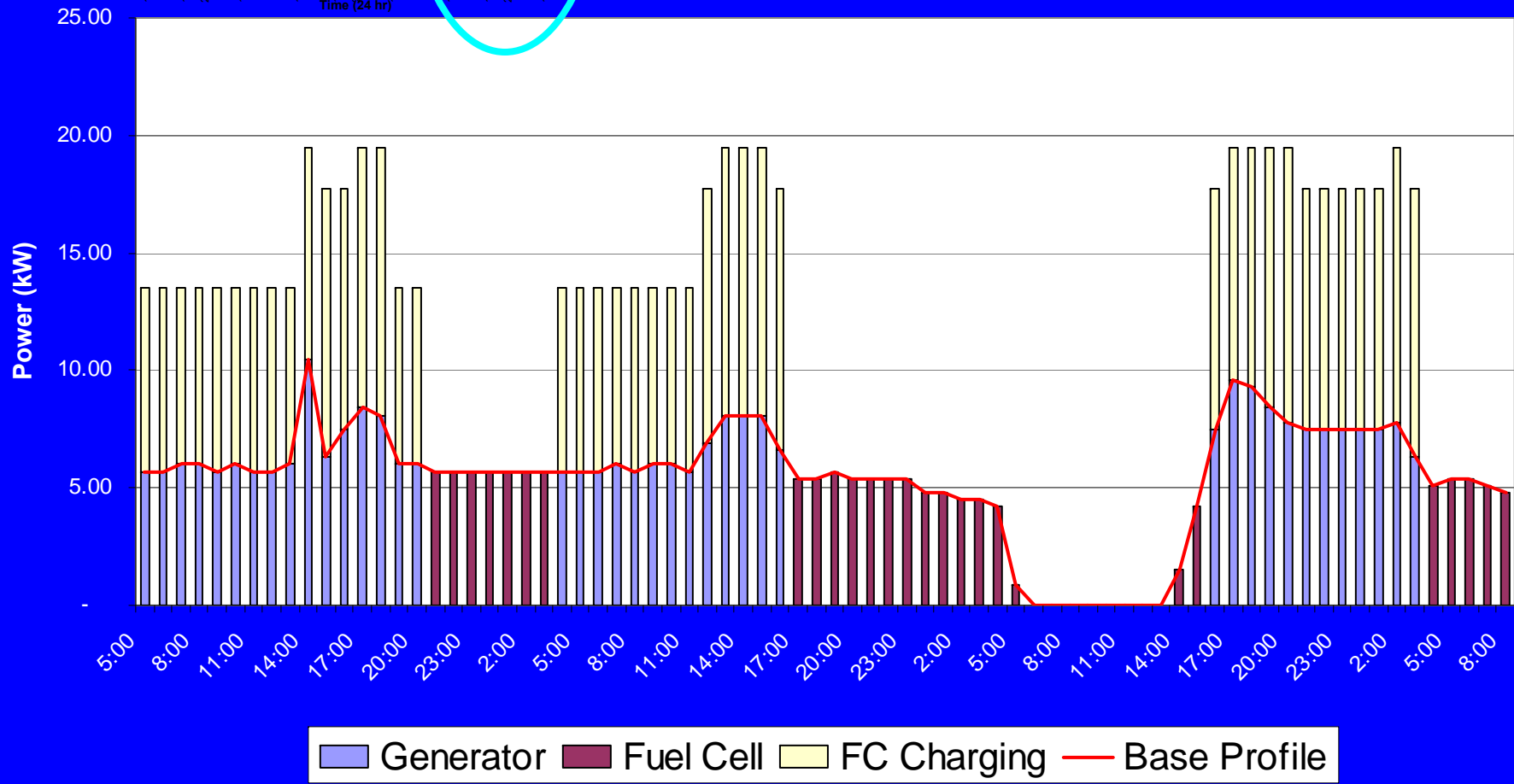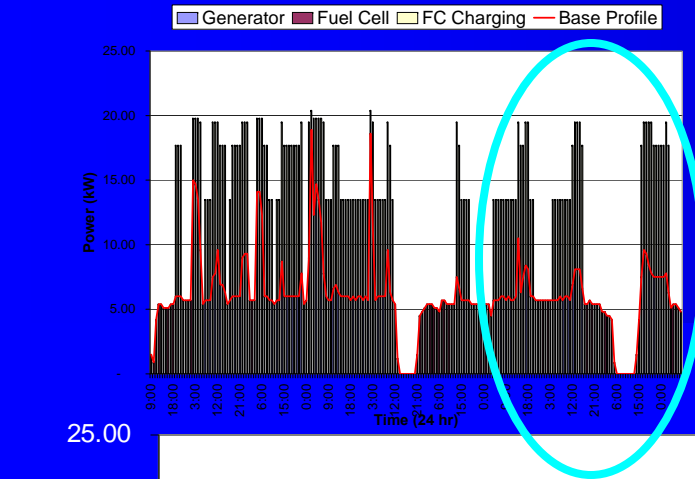
10 kW Fuel Cell, 30 kW Electrolyzer, 30 kW GenSet

TOC Profile Results

- **Profile Covers 9 Days (216 Hours)**
- **No Load For 15 Hours ➔ 201 Total Hours Of Load**

GenSet Cap. (kW)	Electrolyzer Cap. (kW)	Maximize Fuel Savings		Non Negative Fuel Savings	
		Fuel Savings (Gallons)	Fuel Cell Hours	Fuel Savings (Gallons)	Fuel Cell Hours
30	10	1.98	35	0.14	45
30	30	*2.01*	*62*	*0.07*	*76*
60	10	23.37	68	21.71	72
60	60	*52.06*	*144*	*50.97*	*145*

Future Research

- **Maximize Overall Fuel Savings (Regardless of Number of Hours of Silent Camp Operation)**

- **Real-Time Control Strategy With Load Forecasting**

- **Active Wetstacking Protection (Force GenSet Loads ≥ 50%)**

- **Quantify Water Requirements**

- **Quantify Maintenance Savings**

- **Find Optimum GenSet – Electrolyzer - Fuel Cell Combinations**

- **Allow System to Produce Additional H2 for Other Uses**

Acknowledgements

- Mr. Joe Bush, ERDC-CERL for the Silent Camp Algorithm Development & MATLAB Programming

- Dr. Jack Brouwer and Mr. Tim Brown (Ph.D. Student) at the University of CA – Irvine, National Fuel Cell Research Center (NFCRC) for Consultation and Review

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